AMS-368

STUDIES ON A Commercial Seed Blending Operation

U.S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

PREFACE

The study on which this report is based is part of a larger research project on quality evaluation and development of objective measurement of quality factors in agricultural products. This study was conducted under the supervision of Louis Feinstein and Calvin Golumbic.

Therese Kelleher, mathematical statistician, Statistical Standards Division, gave invaluable assistance in developing the statistical phases of the research, and in the preparation of the analyses of data.

Harold A. Kramer, agricultural engineer, Biological Sciences Branch, provided assistance in the planning and sampling phases of this study.

Many individuals in the seed industry provided assistance during the study. The author wishes to thank the following companies for making their facilities available or supplying the equipment used in this study: Mitchell-Hill Seed Co., St. Joseph, Mo.; Twin City Seed Co., Minneapolis, Minn.; Teweles Seed Co., Minneapolis, Minn.; Ramy Seed Co., Mankato, Minn.; Corneli Seed Co., St. Louis, Mo.; Seedburo Equipment Co., Chicago, Ill.; and Burrows Equipment Co., Chicago, Ill.

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SUMMARY

Two tests were made on a commercial seed-blending operation. In each test, a small lot of light-weight Kentucky bluegrass seed was blended into a larger lot of heavy-weight Kentucky bluegrass seed by allowing the smaller quantity of seeds to dribble into the larger quantity as it was dumped into an elevator boot prior to elevation to a small storage bin. The seeds were distributed by a horizontal auger to a series of bulking bins. Each bin was filled consecutively. The seeds were discharged simultaneously from the bins onto a moving endless belt and then recirculated through the bins before bagging.

This blending system did not produce seed lots having uniform distributions of the light-weight seeds. Failure of the system to blend to a desired uniformity is attributed mainly to the failure to introduce the contents of the two lots in a proportional manner. Another contributing factor was the variability in the larger lots before they were blended with the smaller lots of light-weight seeds.

Analysis of the data from the several lots shows that an effective mixing action occurred while the seeds were recirculated through the bulking bins. Testing the effects of the several sources of variation on the content of the light-weight seeds in the several lots showed that the relative importance of several of the effects changed during the blending operation. Reduction in the effect of several sources of variation and reduction of extreme values for the light-weight content found after the blending operation demonstrates the potential effectiveness of this blending system.

A metering device that apportions the amount of material from several separate sources will improve the effectiveness of this blending system. However, such a device will not compensate for extremely large variations in the test factor in the lots to be blended.

Recommendations are: (1) lots to be blended should be relatively free of extreme variations for the test factor; (2) seeds from several sources should enter the system through meters to insure a proportional introduction of the components; and (3) the seed mass should be recirculated through a series of bulking bins.

STUDIES ON A COMMERCIAL SEED-BLENDING OPERATION

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INTRODUCTION

Many seed lots in commercial channels are not uniform. Kent reviewed the literature in this field and also reported the results of his studies on 18 commercial seed lots (4).[1] He found 13 lots to be heterogeneous for one-half or more of the items tested and five to be homogeneous for one-half or more of the items tested. Of this last group, only one lot was homogeneous for all items. The items tested in these studies were pure seed content, weed seed content, number of individual weed seeds or crop seeds, number of noxious weed seeds, and germination percentages. Homogeneity of the lots was determined by the test recommended by Leggatt (6) and published in the International Rules for Seed Testing (3).

Several blending programs patterned after those described by Kent were tested by the present author (2). These programs ranged from a simple dumping of the seeds into a model bin from which the seeds were bagged, to a more complex program in which the seeds from several sources were dumped simultaneously and proportionally, with or without metering of the flow from the several sources, into a model storage unit and passed through a mixing system. During the mixing phase of the more complex blending programs, the seeds were divided into smaller quantities, recombined, and recirculated through this system at least one more time. None of the blending programs studied resulted in a uniform distribution of the test component in each trial as determined by the homogeneity test referred to above. However, relatively higher degrees of uniformity were obtained when the more complex programs were used to blend seeds than when programs lacking division and recirculation of the seed were used. The results of laboratory tests showed that failure to introduce the seeds proportionally and failure to recirculate the seeds through the mixing system always resulted in relatively low degrees of uniformity.

A number of seed companies were visited to observe their blending facilities and to discuss the features believed to facilitate uniform blending. In cooperative agreement, one company agreed to provide facilities, labor, and seed. The U. S. Department of Agriculture agreed to supervise the tests, to take and analyze the samples, and to determine the effectiveness of the blending operation.

Light-weight Kentucky bluegrass seed was chosen for these studies because one of the most difficult problems in blending grass seeds is obtaining a uniform distribution of the light-weight material. In each of two studies, a small lot of light-weight Kentucky bluegrass seed was mixed with a large lot of heavy Kentucky bluegrass seed, and the distribution of the light-weight seed in the blends was analyzed.

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[1] Underscored figures in parenthesis refer to Literature Cited, page 14.

PROCEDURE

Blending

The lots used in the bulking operation were dumped simultaneously into a chute leading to an elevator. The smaller lot was allowed to dribble into the chute while the larger lot was dumped at a much faster rate. The combined lot was elevated to a small holding bin above the bulking bins. The seeds then flowed to a horizontal auger which distributed the seeds to bulking bins arranged in a row beneath the auger. Each bin was filled consecutively.

During the blending operation, seeds were discharged simultaneously from each of the several bulking bins onto a moving endless belt passing beneath the bins. The seeds discharged from the belt into the boot of a second elevator which lifted the seeds to a location slightly above the horizontal auger. Here the seeds were automatically divided into two streams, one of which went to an automatic scale for bagging, while the other stream returned to the bulking bins for recirculation.

During the early part of the operation, seeds going to the scales were dumped, re-elevated, and returned to the bulking bins. During the bagging operation, the stream of seeds going to the scales was bagged immediately while the other stream returned again to the bulking bins. The blending operation continued as long as seeds were returned to the bins. The larger lots used in this study had already been passed through this system at least one time following the cleaning process.

Sampling

Samples from bags of the original seed lots were taken with a double-sleeve, 30-inch probe, modified to have only three long slots running its length rather than the nine short slots usually found. These samples were taken along each of the two long diagonals from top to bottom of each bag (8). Each bag of the lots used in the bulking operation was sampled in the same sequence in which it was later dumped. Each bag of the two resultant lots was sampled in the sequence in which it left the bagging operation.

Samples were also taken during the dumping operation by cutting the stream of seeds in the chute leading to the elevator boot at 30-second intervals.

Each sample was placed in an individual envelope and identified in relation to the sequence in which it was taken. Samples from bags were also identified as to the direction of sampling, that is, whether the probe entered the bag at the left or right upper corner of the bag.

Each sample was mixed thoroughly (9) by passing it through a small laboratory-sized Boerner divider.[2] The samples were then divided into subsamples of approximately 1 gram (not less than 0.900 gram nor more than 1.099 grams of seeds).

Testing

In an attempt to remove a source of human error, the light- and heavy-weight seeds in the samples were separated by the air blast method. Studies by Leggatt (5) and Porter (7) have shown that the use of a standardized method of separation based on a uniform air pressure gives results well within the range of natural variability. The air-blast separation of the seeds in this study was done on a Hearson Improved Ottawa-Type Seed Blower calibrated against a standard sample prepared by the Seed Research Laboratory

[2] The mention of specific instruments is for the purpose of identification and does not imply endorsement by the U. S. Government.

of the Canadian Department of Agriculture. All subsamples were separated at this setting under air pressure for 5 minutes. The portion of seeds in a sample that was blown over at this setting was the light-weight content of the sample, that which remained in the cup was the heavy content of the sample. Periodic checks were made against the standard sample to determine the stability of the calibration under prevailing laboratory conditions. Uniform air pressure was maintained with a blower driven by a constant speed motor. A voltage regulator was used to maintain a constant 110 volts.

The information gathered in this study was treated statistically by an analysis of variance (1) and the homogeneity test (3). The distribution of light-weight components of samples from the bags of the various lots, both before and after blending, and from the samples taken during the dumping operations are compared graphically (fig. 1 and 2).

RESULTS

The statistical evaluation of the data by the analysis of variance test not only showed that the light-weight material was not evenly distributed throughout the several lots, but also indicated the relative importance of several sources of variation both before and after blending. These sources of variation were: (a) differences between the contents of the various bags, (b) differences between the contents of two samples taken from the same bag, and (c) differences between the subsamples from the same sample. Samples from the same bag were tested for the effect of direction of sampling and for that of residual error. The residual error is a measure of the actual variability of the differences between the samples within bags after the directional variability has been removed. If these differences between the samples were constant, the residual variability would be zero and all of the within bag variability would be accounted for by the directional differences. If the blending operations had been effective and had resulted in a uniform lot, the mean squares for all sources of variance in the analysis of variance would be expected to be the same.

The first blending operation, bulking 2-1/2 bags of lot A with 68 bags of lot B, resulted in the blended lot AB, consisting of 69-1/2 bags. In the second blending operation, 2 bags of lot C were bulked with 62 bags of lot D resulting in the blended lot CD consisting of 63-1/4 bags. (Reference to table 1 showing the characteristics of the lots used will show that 2 bags of lots A and C were essentially equivalent to the weight of 1 bag in lots B and D. The bulkiness of the light-weight seeds brought about a volume slightly larger than the equivalent volume in heavy seeds.) For the purposes of this study, fractions of bags will be considered as a single unit and will have the same importance as any other bag in the lot.

TABLE 1.--Characteristics of the various seed lots before and after blending

Lot	No. of bags	Total weight of lot	Bushel-Weight	Mean content of light weight material
		Pounds	*Pounds/bushel*	*Percent*
A....................	2½	125	10	64.64
B....................	68	6800	22	6.05
AB[1]..................	69½	6925	--	7.20
C....................	2	100	9	76.96
D....................	62	6200	22	8.46
CD[2]..................	63¼	6300	--	9.17

[1] Blended lot AB is the blend of lot A and lot B.
[2] Blended lot CD is the blend of lot C and lot D.

Analyses of variance were not made on the contents of lots A and C because of their relatively small sizes. Analyses of variance were made on lots B and D and the blended lots AB and CD.

Lot B

As described in the sampling procedure above, 136 samples were taken from the 68 bags of this lot. The statistical analysis of the data obtained from the air-blast separation of the light-weight material of the 1,085 subsamples of the lot showed that the distribution of the light weight material was not uniform (table 2.) The single source of variance contributing the greatest effect in the overall variability was that associated with the differences in the light-weight content of the several bags in the lot. Differences in the distribution of the light-weight content in the same bag also contributed greatly to the overall variability. The differences of the content within the same bag were found to be due to differences between samples (the residual error) rather than to differences between the direction of sampling. This lot then is characterized by large variations between the contents of the various bags of the lot and by differences in the content of the same bag which cannot be characterized by a segregation toward any one position in the bag.

TABLE 2.--The analyses of variances for lots B, blended lot AB, lot D, and blended lot CD

Source of variation	Degrees of freedom	Sum of squares	Mean square	Component of variance
Lot B				
TOTAL................................	1084	421.0574	--	--
Between bags........................	67	291.4998	4.3507	0.2130
Between samples in same bag.........	68	64.7577	0.9523	0.1108
Between directions of sampling....	1	0.1216	0.1216	--
Residual error between samples....	67	64.6361	0.9647	--
Between subsamples in same sample...	949	64.7996	0.0683	0.0683
Blended lot AB[1]				
TOTAL................................	1115	647.3674	--	--
Between bags........................	69	492.5818	7.1389	0.3708
Between samples in same bag.........	70	85.5786	1.2226	0.1444
Between direction of sampling.....	1	4.9072	4.9072	--
Residual error between samples....	69	80.6714	1.1692	--
Between subsamples in same sample...	949	69.2070	0.0709	0.0709
Lot D				
TOTAL................................	619	437.5969	--	--
Between bags........................	61	280.6990	4.6016	0.2972
Between samples in same bag.........	62	101.0319	1.6295	0.3034
Between directions of sampling....	1	40.4023	40.4023	--
Residual error between samples....	61	60.2296	0.9939	--
Between subsamples in same sample...	496	55.8660	0.1126	0.1126
Blended lot CD[2]				
TOTAL................................	639	510.0042	--	--
Between bags........................	63	279.3214	4.4337	0.1672
Between samples in same bag.........	64	176.7774	2.7621	0.5314
Between directions of sampling....	1	14.1283	14.1283	--
Residual error between samples....	63	162.6491	2.5817	--
Between subsamples in same sample...	512	53.9054	0.1053	0.1053

[1] Blended lot AB is the blend of lot A and lot B.
[2] Blended lot CD is the blend of lot C and lot D.

Blended Lot AB

The analysis of variance for the blended lot AB, based on the separation of light material in 1,116 subsamples obtained from the 140 samples of this lot, showed that the bulking operation did not bring about a uniform distribution of the light-weight material. In fact, an examination of the mean squares will show that lot AB is not as uniform as was lot B. As in lot B, differences between the light-weight content of the various bags and the differences in the contents within the same bag respectively, were found to have the greatest effect on the overall variability in the lot. The differences between the samples from the same bag appeared to reflect a rather consistent difference due to the direction of sampling. Samples taken along one direction of penetration of the bag showed consistently higher values for light-weight content in all bags when compared to the samples taken along the second direction of penetration. While the variability of the differences between the two samples was large and exerted an effect on the variability of the light-weight material in a bag, this effect was considerably less than the corresponding effect of the differences between the directions of sampling. This lot shows the large variations between bags that were found in lot B. The differences found in the contents of the same bag, unlike those found in lot B, show that segregation has occurred which is consistent in relation to the position within the bag.

The average of the light-weight content (mean content) of the blended lot, AB 7.20 percent, was about that expected from the addition of lot A to lot B (7.21 percent).

Lot D

The data for lot D, based on 620 subsamples from the 124 samples of the lot, showed that the distribution of the light-weight material was not uniform. In contrast to the preceding lots, the greatest effect on the over-all variability in this lot was exerted by the differences between the samples taken from the same bag (table 2). However, the effect exerted by the variability between the contents of the several bags in the lot was essentially equal to that of the differences between the samples from the same bag. The variability between the samples from the same bag reflects the effect of the differences between the directions of sampling. While the residual error associated with the failure of the differences between the two samples to be alike does exert a noticeable effect on the within bag variability, the effect is far less than that due to the effect of the differences in the direction of sampling. This lot, then, is characterized by two sources of variability which are almost equal in their effect on the over-all variability of the lot. Within bag variation in this lot is effected to a large extent by a rather consistent segregation of material in a bag and extending throughout the lot.

Blended Lot CD

The analysis of the data for the 640 subsamples representing the two samples from each bag of this lot again indicates the failure to obtain a uniform distribution of the light-weight material. An examination of the mean squares for lot CD shows that the distribution of the light-weight material was not as uniform as that of lot D. The overall variability of the blended lot was most affected by the differences between the samples taken from the same bag. The effects of the two separate sources causing this difference have been shifted in the relative importance exerted by each when compared to the situation in lot D. The actual differences between the two samples in the bag has been increased. The differences between the contents of the several bags are still large enough to effect the overall variability of the lot, but the relative importance of this effect compared to the same effect in lot D is considerably less. This lot is characterized by differences between the contents of the same bag. This is due in part to a somewhat consistent segregation of the material in the bag in relation to the direction of sampling. However, a significantly larger effect than found in the preceding lot is due to the additional differences between the two samples that is not accounted for by the directional segregation. Differences between the contents of the several bags plays a relatively less important part in this lot than it did in lot D.

The overall sample average of blended lot CD, 9.17 percent, is not significantly different from the expected mean content, 9.55 percent.

Additional Tests

The data obtained from the separations of light-weight material discussed for the four lots were also tested by applying the homogeneity test as recommended by Leggatt and published in the International Rules for Seed Testing. The results of these tests showed all four lots to be heterogeneous for the distribution of the light-weight content of the lots. The results of the homogeneity test are presented in table 3 and are compared to the homogeneity limits set forth in the rules for conducting the test (3). While the homogeneity test is useful in determining the uniformity of the distribution of a given test item, it does not give information concerning the relative importance of the effect of the several differences on the overall variability of the lot.

Figures 1 and 2 show the distribution of the light-weight material during the three phases of sampling; in the original lots, during the dumping operation, and in the resultant lots. They indicate that the failure to blend to uniformity is due, to a large extent, to the failure to introduce the components proportionally. These graphs also show that the recirculation of the seed mass through the bulking bins does reduce some of the large variations found during the dumping phase of this operation.

To study further the distribution uniformity, a range reasonably expected to include the majority of the individual estimates of light-weight content, was calculated for each

TABLE 3.--Homogeneity values for the lots studied

Lot	Number of bags	Average number of tests per bag	Homogeneity value	Limit for homogeneity
B....................	68	16	61.50	1.96
AB[1]....................	70	16	78.75	1.96
D....................	62	10	46.34	1.96
CD[2]....................	64	10	43.82	1.96

Formula for homogeneity value when more than 31 bags are sampled:

$$\text{Homogeneity value} = \sqrt{2\left[\frac{\left(\frac{\text{Sum } X^2}{\overline{X}} - \text{Sum } X\right) K}{1 - \frac{\overline{X}}{100}}\right]} - \sqrt{2N-3}$$

Where: X = mean percentage content per bag (based on 2 samples per bag)
$\overline{X}$ = mean content of lot
K = number of seeds (in hundreds) tested per bag
N = number of bags tested

[1] Blended lot AB is the blend of lot A and lot B.
[2] Blended lot CD is the blend of lot C and lot D.

lot. The 0.95 confidence limits were used in the calculation of these ranges (table 4). If the lot were uniform, no more than four bags would have content values exceeding this range in all of the lots studied. The numbers of bags in which the content value exceeded this limit are:

Lot B................................	27 bags
Blended lot AB	24 bags
Lot D	13 bags
Blended lot CD	5 bags

TABLE 4.--Comparison of the 0.95 confidence range for the means of the four lots when all of the bags in the lot are sampled

Lot	Standard deviation[1] of a lot mean expressed as percentage	2 x standard deviation	Estimated lot mean	Range
			Percent	*Percent*
B.................	0.2440	0.4880	6.05	5.56-6.54
AB[2]..............	0.2764	0.5528	7.20	6.65-7.75
D.................	0.4037	0.8074	8.46	7.65-9.27
CD[3]..............	0.5255	1.0510	9.17	8.12-10.22

[1] Statistical formula for these data:

$$\text{standard deviation} = \sqrt{\frac{N-n}{N}\sigma_b^2 + \frac{\sigma_p^2}{2} + \frac{\sigma_e^2}{2K}}$$

where: N = number of bags in the lot
n = number of bags sampled
2 = number of samples in each bag
k = average number of subsamples per sample
σ_b^2 = portion of variance due to differences between bags
σ_p^2 = portion of variance due to difference between samples in same bag
σ_e^2 = portion of variance due to difference between subsamples in same sample

When all of the bags in a lot are sampled, this formula becomes:

$$\text{standard deviation} = \sqrt{\frac{\sigma_p^2}{2} + \frac{\sigma_e^2}{2K}} \quad \text{(Estimated by)} \sqrt{\frac{\text{MS samples}}{2K}}$$

MS samples = mean square for samples in analysis of variance table for each lot.

[2] Blended lot AB is the blend of lot A and lot B.
[3] Blended lot CD is the blend of lot C and lot D.

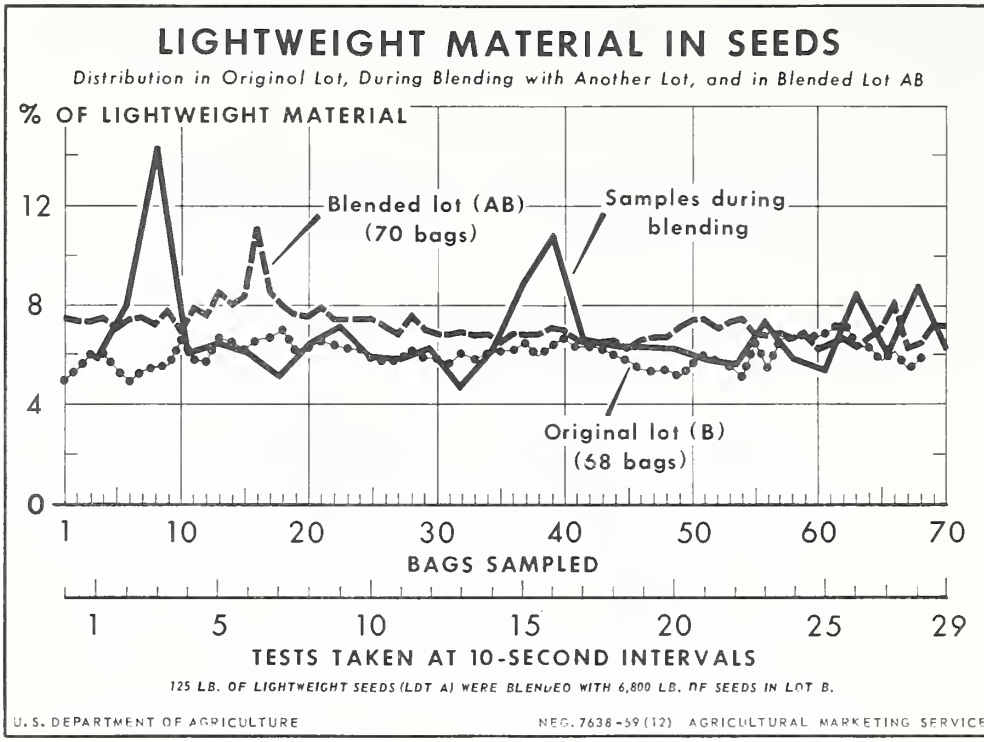

Figure 1.

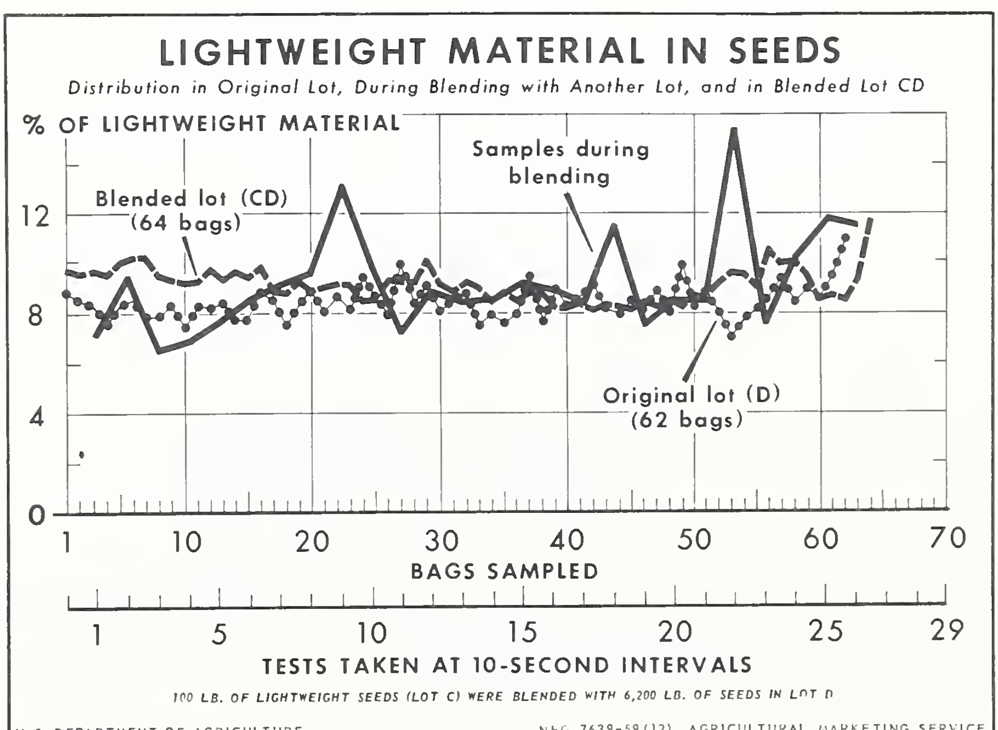

Figure 2.

CONCLUSIONS

The reduction of extreme differences found during the dumping phases of the blending operation (figs. 1 and 2), shows that effective mixing occurred while the seeds were recirculated through the bulking bins. This is substantiated by the shifting of the relative importance of the effects of several differences on the overall vairability of the lot as found in both blended lots.

The presence of the relatively large effects due to the differences in the direction of sampling indicated that a rather consistent segregation is present in the bags. Since this difference is directional, it is believed to result from the bagging operation.

Failure of the operation to produce uniform distribution is believed to be caused by the failure to introduce the components proportionally as well as by the variability in lots B and D. While a metering device would assure a more propotional introduction of material from several sources, it would not compensate for the internal variability of any one component. This variability may be overcome by a thorough mixing of the component lot before it is mixed with other lots.

A blending program or system recommended to bring about a relatively high degree of uniformity may be based on the following plan:

(1) The quantities, or lots, of seeds to be blended should be relatively free from extreme variations within themselves. A lot believed to possess such variations should be divided into several parts and these parts thoroughly mixed prior to mixing with other lots.

(2) Seeds to be blended, from two or more distinct lots or sources, should be introduced from separate bins containing one lot only.

(3) The seeds from the several bins should be metered to assure a proportional introduction of the component parts.

(4) The contents of the combined seed mass should be placed in several bins with each bin being filled consecutively. Streams from these bins should be metered to assure proportional feed from each bin.

(5) The seed should be recirculated through this series of bins at least a second time or as often as required to bring about an even distribution of the component most difficult to mix. A similar passage of the seeds through one or more additional series of bulking bins may be substituted for the recirculation of the seeds through the same series of bins.

This basic plan may be modified to suit the individual company's requirements of space and equipment.

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